NASA CR 65613

SPACELABS, INC.

QUARTERLY PROGRESS REPORT NO. 1
CONTRACT NO. NAS 9-6649
PROPELLANT LEAKAGE DETECTION SYSTEM

This report covers the period from December 1, 1966 to February 28, 1967.

1.0 GENERAL PROGRESS

During the initial three-month period, the major effort has been directed toward the detection of leakage flow rates. Graphs of the significant fluid properties for the various dimensionless parameters used in heat transfer as a function of temperature have been developed (Figures 3 - 6). The information contained in the working graphs has been plotted independent of system characteristic dimensions so that variations in configuration can be readily evaluated. In addition, the data will permit selection of fluids that will simulate the oxidizer and the fuel, and help evaluate the temperature compensation required.

A preliminary investigation for suitable probe and housing materials has been completed.

Staffing has been augmented in the last two weeks of this reporting period with the addition of a Senior Technical Specialist in flow dynamics.

2.0 PROGRAM SCHEDULE

The program is on schedule as shown on the detailed Program Schedule presented in Figure 1.

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HOUSTON, TEXAS

3.0 FLUID SIMULATION

The simulation of the oxidizer and fuel by means of other fluids requires that certain properties, or combinations of properties, of the fluid be similar. In an electrothermal flowmeter, the changing characteristics of the heat transfer coefficient with flow velocity is used to determine flow rates. The parameters of concern are the heat transfer coefficients for natural and forced convection. These are plotted in Figures 7 and 8, respectively, as a function of temperature. H_2O, CS_2, and CCl_4, or a mixture of these fluids (Figures 7 and 8) may be used as substitutes for the oxidizer or fuel.

4.0 GRAVITATIONAL EFFECTS

Due to the minute flow rates being measured, it is important that natural convection errors be minimized. Figures 7 and 8 present the relative magnitude of the natural convection heat transfer coefficient (h_c) and the forced convection heat transfer coefficient (h_f). Both heat transfer coefficients were analytically calculated assuming a sphere of 1/4-inch diameter and a $\Delta t = 5°F$. The forced convection coefficient assumed a flow velocity based on the leakage rate of 25 cc/hr.

Examination of the curve for N_2O_4 indicates that the heat transfer coefficient for forced convection at the threshold leakage rate (25 cc/hr) is an order of magnitude less than the heat transfer coefficient for natural convection. To obtain an indication of leakage flow rates that is repeatable requires that the changes in h_c as a function of temperature and system orientation be minimized. This was verified by experimental data obtained during the Phase I development program which indicated the PLDS configuration used then to be very sensitive to orientation.

Two different configurations are presently being investigated:

(1) A spherical heater-sensor body immersed in mid-stream.

(2) A three-probe heater-sensor spread 120° apart on the housing with a spherical sensor located in the geometric center of the heater-sensor probes.

Both configurations are presently being investigated for changes in the natural convection heat transfer coefficients with orientation. Electric measurements and dye visualization are being used to study the natural convection phenomena. Figure 2 is a diagram of the three-probe unit to be tested.

5.0 MATERIALS

A list of materials to be used for sensor probe and housing has been compiled and is presented in Table I. This table will be periodically updated. These materials were reviewed for their compatibility with the oxidizer and fuel as well as for their thermal conductivity.

High thermal conductivity is desirable for the heater and sensor body to minimize the required power to couple energy into the fluid stream and to minimize the sensor time constant.

6.0 WORK TO BE PERFORMED IN THE NEXT QUARTER

(a) Evaluate and select the simulating fluids.

(b) Develop configurations to minimize natural convection errors due to orientation.

TABLE I

Compatible Materials with:		Thermal Conductivity $k\ (\frac{BTU}{hr\text{-}ft^2\text{-}°F/ft})$
I	Hydrazine based fuels:	
	1. Aluminum Alloys (2S, 24S)	69 - 128
	2. Cadmium	65
	3. Stainless Steel (300-series)	9 - 12
II	Nitrogen Tetroxide	
	1. Aluminum	131
	2. Nickel	40
	3. Carbon Steel	21 - 31
	4. Stainless Steel (300-series)	9 - 12

(c) Determine temperature compensation schemes.

(d) Conduct error analysis on the electronic circuitry.

(e) Begin experimental evaluation of specific system mechanical and electronic configurations.

7.0 MISCELLANEOUS

A Senior Technical Specialist in flow dynamics, Rod Mc Gann, joined Spacelabs on 27 February 1967. Mr. Mc Gann was responsible for the cabin conditioning and anti-icing systems for Northrup Aircraft, designed hydraulic servo valves and torque motors at Bendix Aviation, was Supervisor of the Thermodynamics Group at Radioplane, and most recently directed the analytical evaluation of a hypersonic accelerator for the Air Force while with Texaco Experiment, Inc. He has sixteen years of experience and is a registered mechanical engineer in the State of California. His primary assignment is to the PLDS program.

APPENDIX

DESCRIPTION OF GRAPHS

1) Figure 3 - Grashoff Number ($Gr = \frac{g \beta L^3 \theta_s}{\nu^2}$)

Plot of $A = \frac{g \beta}{\nu^2}$ Versus Temperature

2) Figure 4 - Nusselts Number ($Nu = \frac{h D}{k}$)

Plot of $B = \frac{1}{k}$ Versus Temperature

3) Figure 5 - Reynolds Number ($Re = \frac{\rho V D}{\mu}$)

Plot of $C = \frac{\rho}{\mu}$ Versus Temperature

4) Figure 6 - Prandtl Number ($Pr = \frac{Cp \mu}{k}$)

Plot of Pr Versus Temperature

5) Figure 7 - Plot of the h_c (Natural convection heat transfer coefficient) versus temperature.

The equation plotted is given by:

$$Nu = 0.53 (Gr\ Pr)^{1/4}$$

where Nu is determined graphically from the equation:

$$Nu^{e-2/Nu} = 0.162 (Gr\ Pr)^{1/3}$$

6) Figure 8 - Plot of h_f (forced convection heat transfer coefficient) versus temperature for a constant velocity (low flow threshold velocity) and a spherical body (1/4-inch diameter).

The equation plotted is given by:

$$Nu = 0.55\ Pr\ (Re)^{1/2}$$

NOMENCLATURE

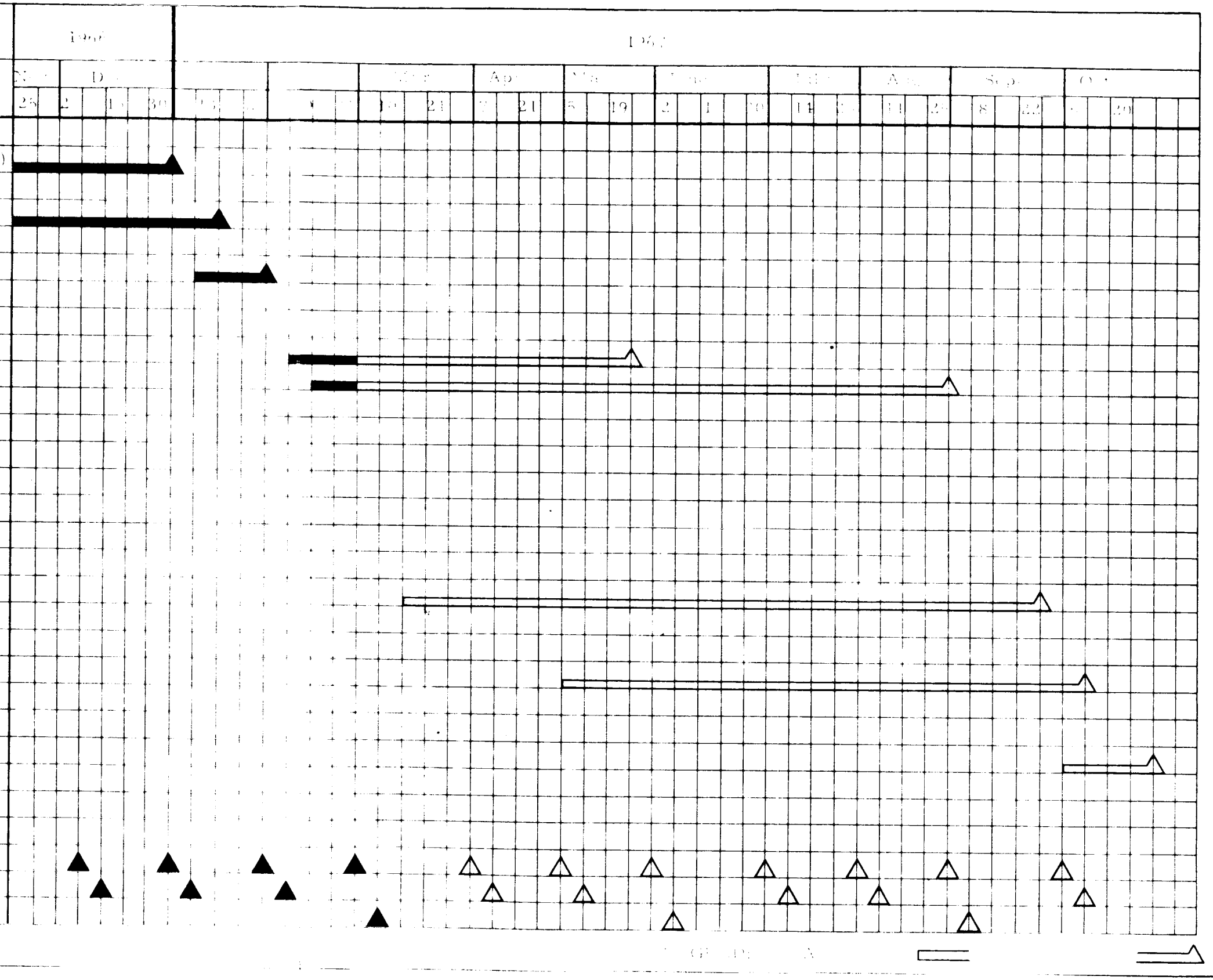
h	Coefficient of Heat Transfer
D	Diameter
k	Thermal Conductivity
ρ	Density
V	Velocity
μ	Dynamic Viscosity
a	$\frac{k}{\rho C_p}$
g	Acceleration of Gravity
B	Coefficient of Thermal Expansion
L	Length
θ_s	Temperature Difference
v	Kinematic Viscosity $\frac{\mu}{\rho}$
$\dot{m}$	$\rho A V$
A	Cross-Sectional Area of Pipe

All units ft., sec., pounds, BTU, °F

SPACELABS, INC. PROGRAM SCHEDULE

5300	PHASE II

PROPELLANT LEAKAGE DETECTION SYSTEM (PLDS)
EVALUATION OF REQUIREMENTS
A. Review and analyze data on PLDS (NAS9-3427)
B. Analyze system requirement - Exhibit "A" Statement of Work (NAS 9-6044)
C. Define problem areas and determine direction of maximum effort
LEAKAGE DETECTOR DESIGN
A. Select simulated propellants
B. Hardware Analysis
1. Mechanical System
a. Flow characteristic for various meter and temperature sensor probes & housing
b. Materials compatibility study
2. Electronic System
a. Circuit design
b. Temperature sensor design
C. Experimental verification of criteria
1. Breadboard evaluation of PLDS
2. Compile data on PLDS
D. Data Reduction
1. Error analysis of data
2. Select optimum system (PLDS)
F. Documentation
1. Schematic, Wiring diagrams, etc.
REPORTS AND REVIEW SESSIONS
A. Review Sessions
B. Monthly Reports
C. Quarterly Reports



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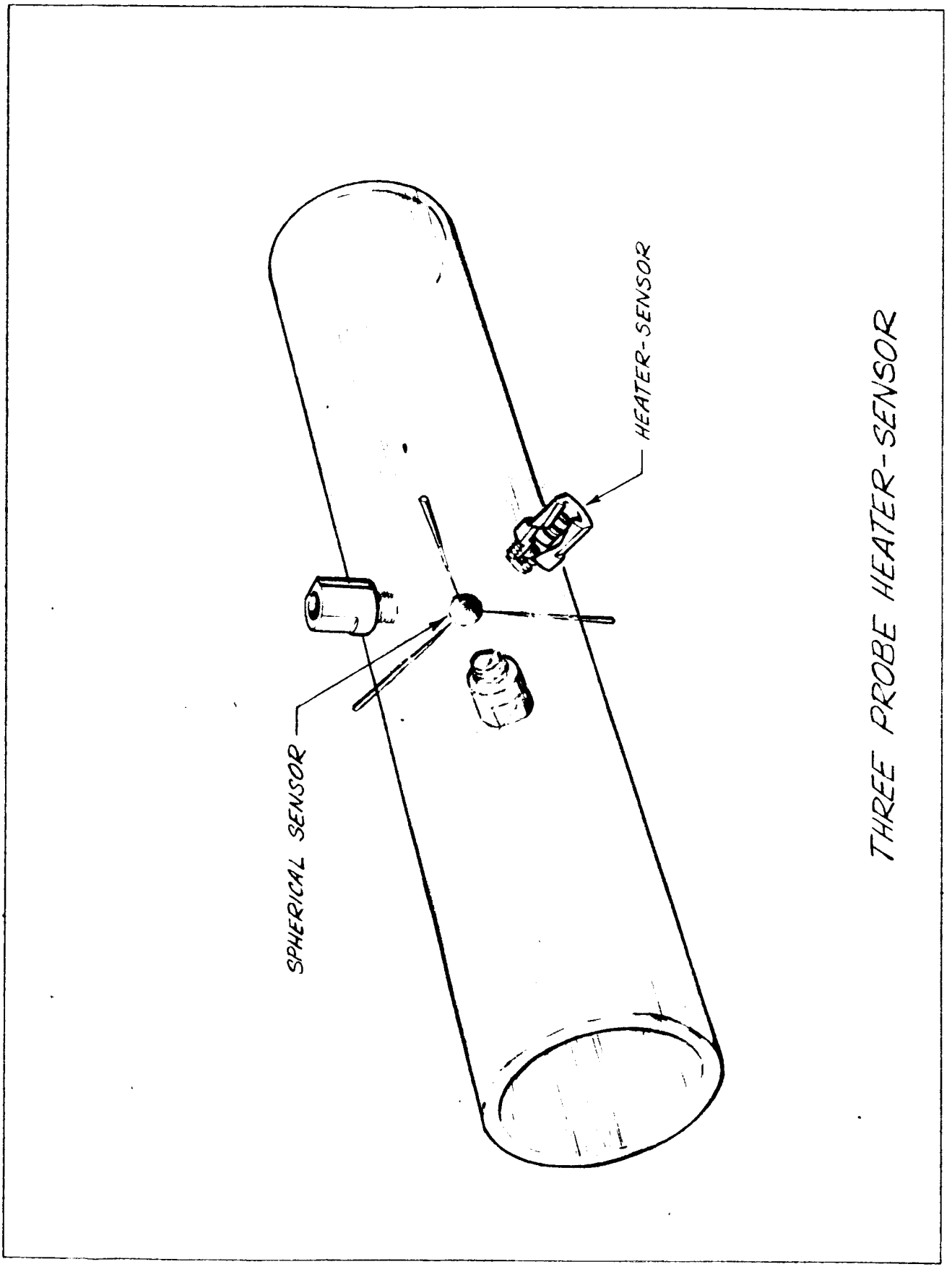

FIGURE 2

SPACELABS, INC. PROGRAM SCHEDULE

5300	PHASE II	1967				1968			
PROPELLANT LEAKAGE DETECTION SYSTEM (PLDS)		Nov		Dec		Jan		Feb	
		3	15	1	15	29	12	26	9	23
PROTOTYPE FABRICATION AND TEST									
A. Fabrication of prototypes (2)									
B. Testing of prototypes									
C. Deliver prototypes									
REPORTS AND REVIEW SESSIONS									
A. Review sessions									
B. Monthly reports									
C. Quarterly reports									
D. Final report									

SF 4-115 (6-66)

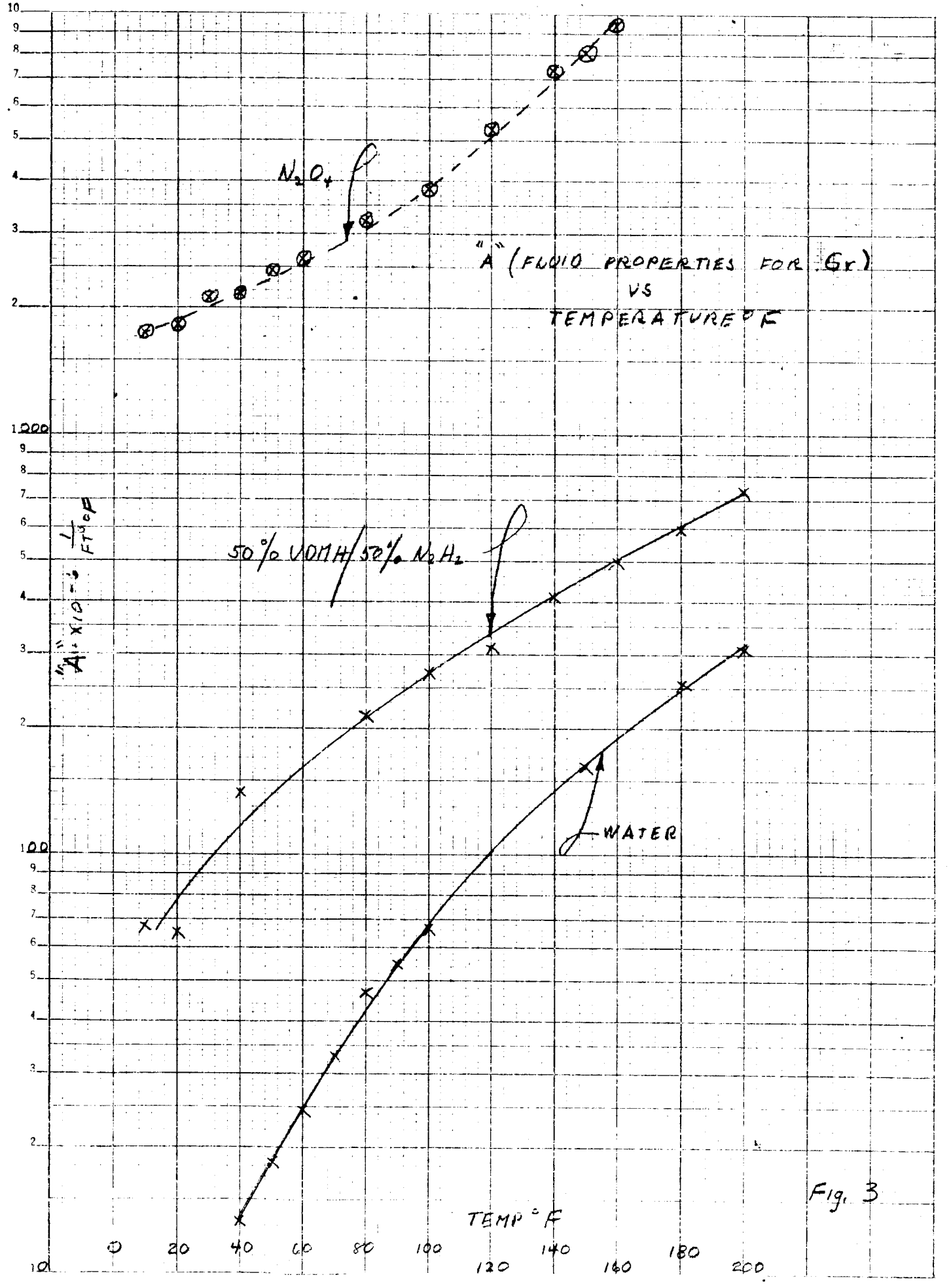

Fig. 3

SEMI-LOGARITHMIC 46 5493
KEUFFEL & ESSER CO.

10 X 10 TO THE CM.
KEUFFEL & ESSER CO.
359-14G

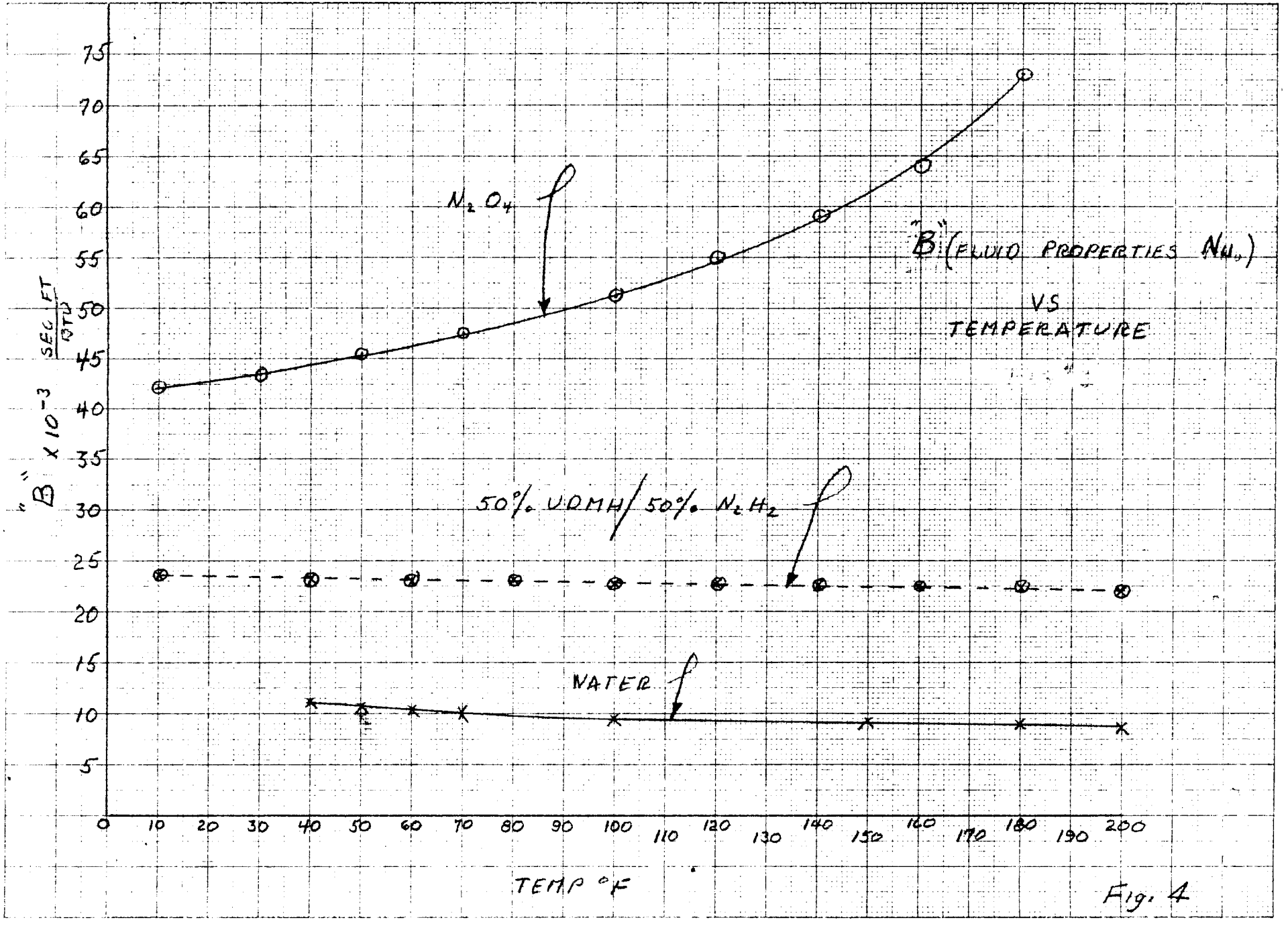

Fig. 4

10 X 10 TO THE CM. KEUFFEL & ESSER CO. 359-14G

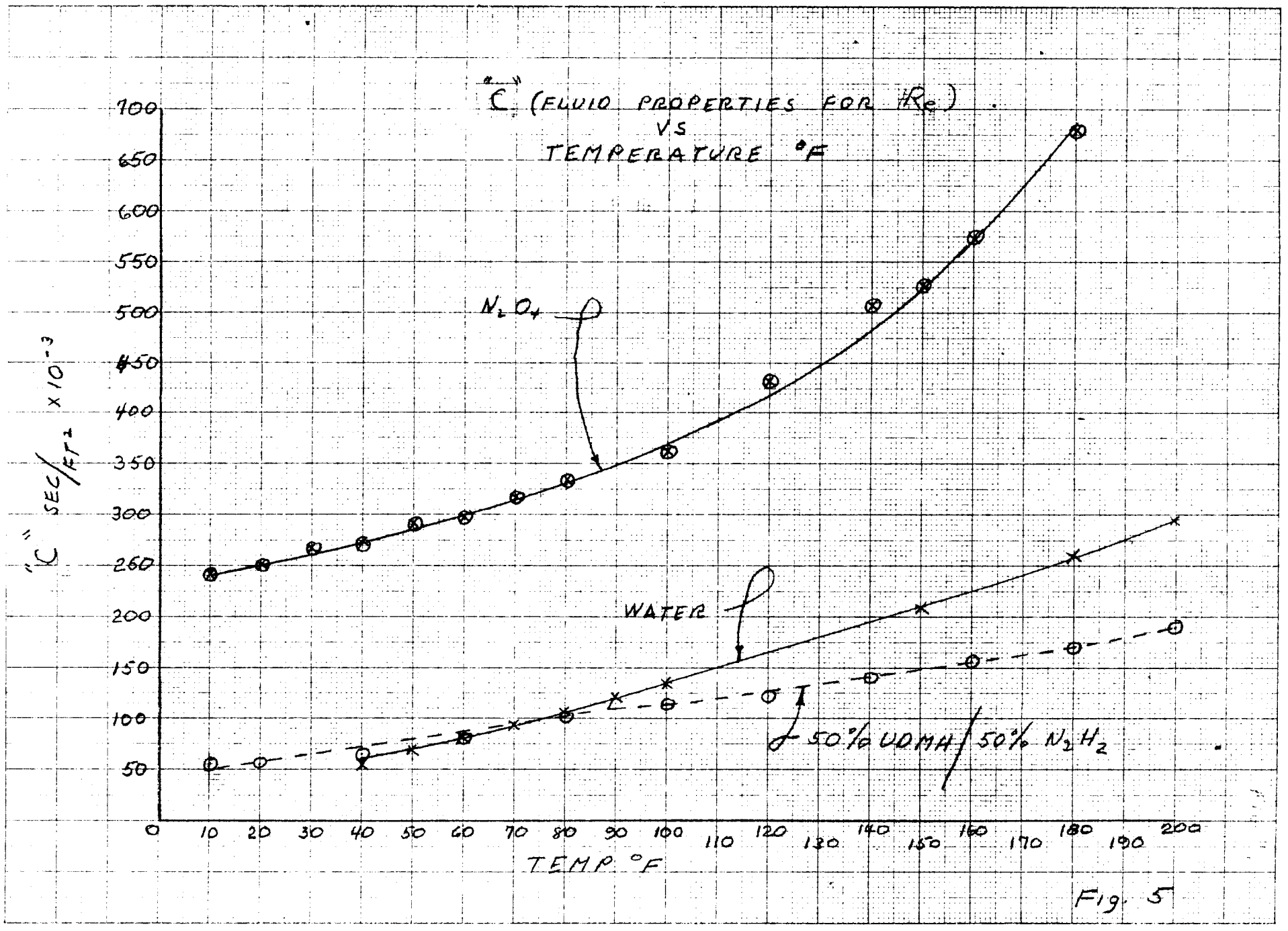

Fig. 5

K+E 10 X 10 TO THE CM. KEUFFEL & ESSER CO. 359-14G MADE IN U.S.A.

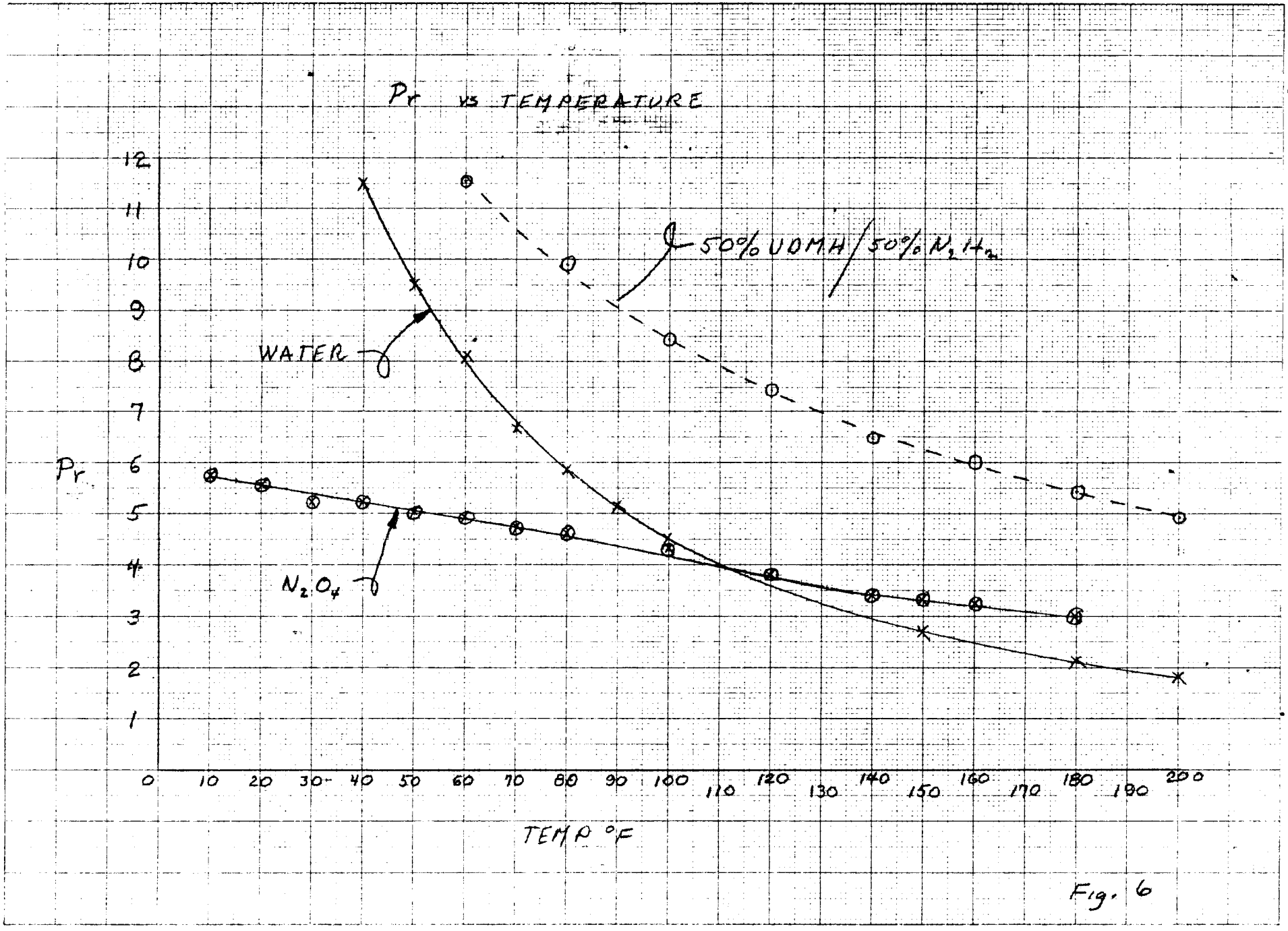

Fig. 6

K&E 10 X 10 TO THE CM. KEUFFEL & ESSER CO. MADE IN U.S.A. 359-14G

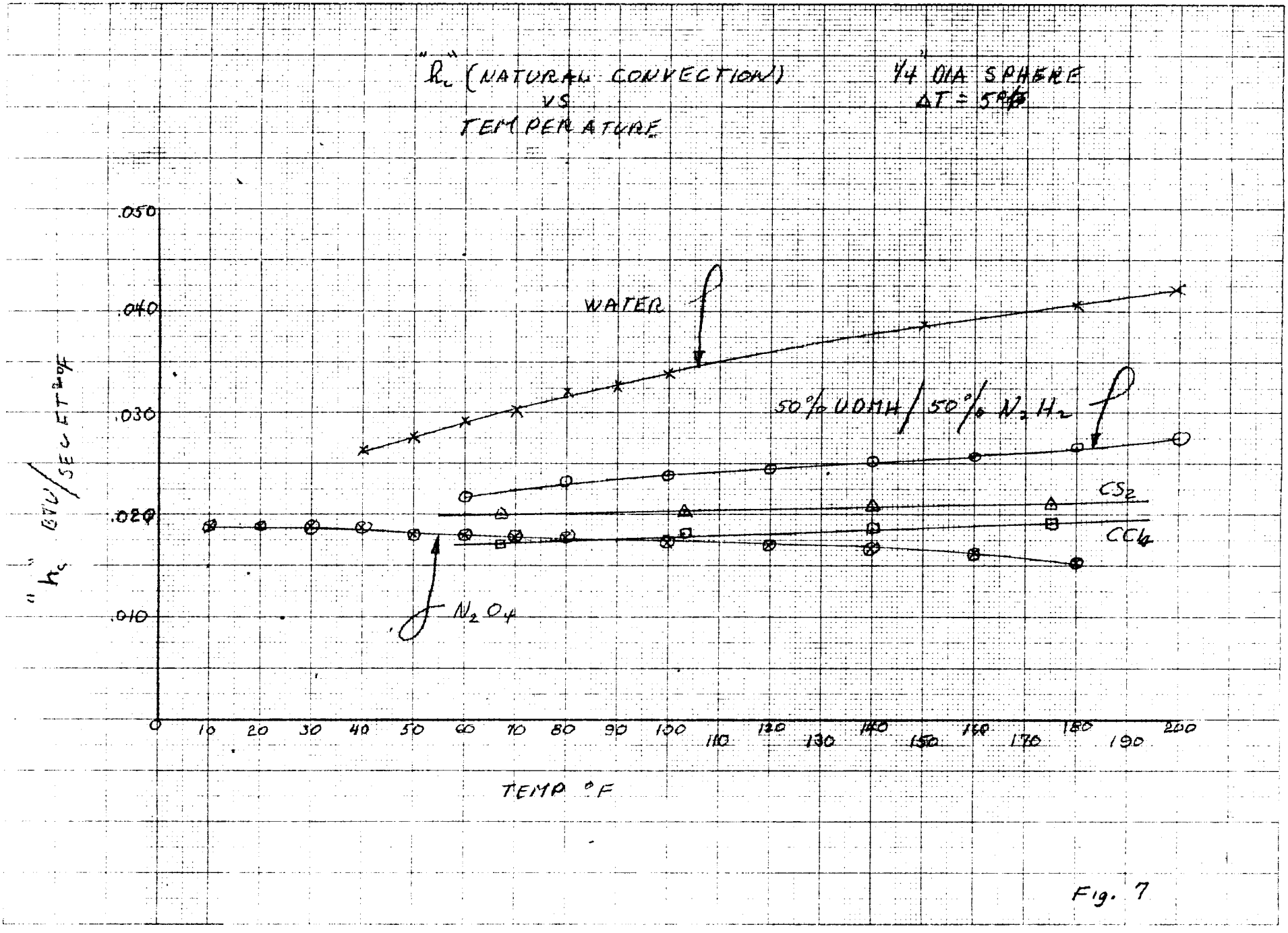

Fig. 7

10 X 10 TO THE CM
KEUFFEL & ESSER CO.
359-14G

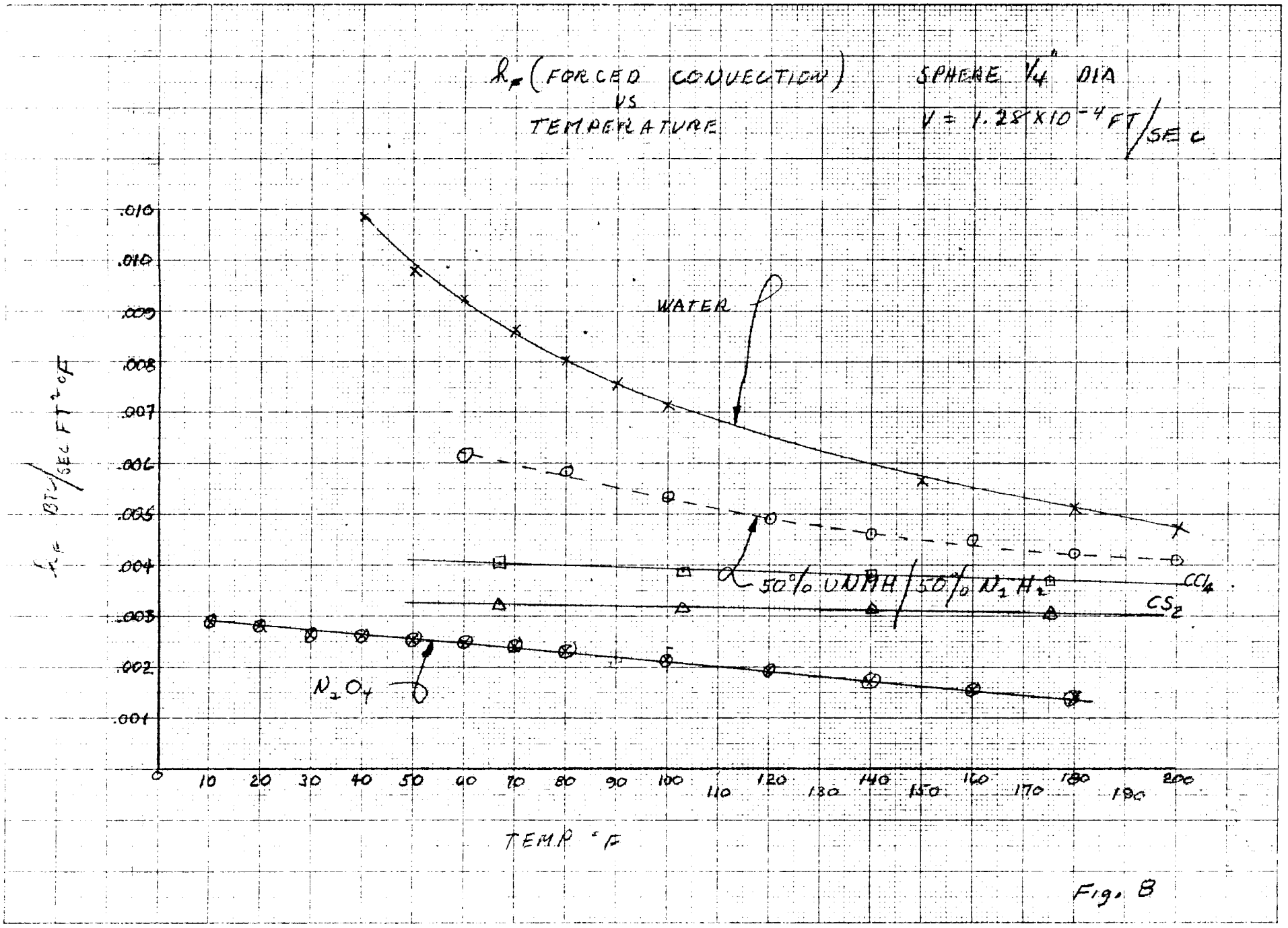

Fig. 8

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1. Mc Adams, William H., "Heat Transmission," Second Edition, McGraw-Hill Book Company, Inc., New York.

2. Eckert, E. R. G., and Drake, R. M., "Heat and Mass Transfer," Second Edition, McGraw-Hill Book Company, Inc., New York, 1959.

3. HSU, S. T., "Engineering Heat Transfer", D. Van Nostrand Company, Inc., New York, 1963.